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GEOGRAPHIC RELATIONS OF THE TRIAS OF CALIFORNIA.[1]

Historical.—Triassic fossils were discovered in California by the State Geological Survey under J. D. Whitney; these were rightly recognized by Gabb[2] as being nearly related to the Upper Triassic Fauna of the Alps, and certain species were even looked upon as identical with European forms. This was the first discovery of marine Trias in the western hemisphere, and the third discovery outside of Europe, the first being that in northern Siberia by Keyserling,[3] the second that in the Himalayas of India, by Strachey,[4] and later described by Salter.[5] Nothing more was done with the Trias in America until the Survey of the Fortieth Parallel discovered it in the Star Peak range of Nevada, where Meek[6] thought he recognized some Californian species. Shortly after this Lower Trias was discovered in southeastern Idaho, by the Hayden Survey, and described by Dr. C. A. White;[7] no Californian species were found here, but this discovery proved the occurrence in the West of a Lower Triassic fauna like that of the Asiatic region.

The next publication on the Californian Trias was by E. von Mojsisovics in *Arktische Triasfaunen*,[8] in which some of Gabb's species are compared with ammonites from Siberia, and the relations of the American faunas to those of the Arctic-Pacific province are discussed.

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[1] Published by permission of the Director of the United States Geological Survey.

[2] Palæont. Calif., I, pp. 19–35.

[3] Bull. phys.-math. de l'Acad. Sci. de St. Petersbourg, Tome V, No. 11.

[4] R. STRACHEY: Quart. Jour. Geol. Soc. (London), Vol. VII, pp. 242–310, 1851.

[5] J. W. SALTER (and H. F. BLANFORD), Palæontology of Niti in the Northern Himalayas, 1865.

[6] Geol. Exp. Fortieth Parallel, Vol. IV, Part I, 1877.

[7] U. S. Geol. and Geol. Surv. Terr., Vol. XII, An. Rep., Part I, 1883.

[8] Mém. Acad. Impér. Sci. St. Petersbourg, VII Ser., Tome XXXIII, No. 6, 1886.

Professor Alpheus Hyatt[1] next undertook a revision of Gabb's work, visiting the original locality and adding largely to the faunal list, and especially to our knowledge of the stratigraphic distribution of the species.

In 1892 the writer's attention was called by Dr. H. W. Fairbanks to a bed of ammonite-bearing limestone near Pitt River in Shasta county; on examination the fossils proved to be of Upper Triassic age. This locality was soon afterwards visited by the writer, who spent the field season of 1893 at work in that region. This work added over fifty species to the known fauna, chiefly of Karnic age, and nearly related to characteristic species from the Tyrolean Alps.[2] The writer has since spent a good part of the field seasons of 1895 and 1898 collecting in that region, and has added greatly to the fossil list, especially of the Ceratitidæ and the Tropitidæ, bringing out even more strongly the relations with the Alpine Trias. A part of these results has already been published.[3]

The latest paper on the Triassic stratigraphy of California is by Dr. E. von Mojsisovics,[4] who, on the basis of communications of Professor Hyatt and the writer, and a suite of fossils sent him by the writer, compares at considerable length the American to the European Upper Triassic faunas.

The accompanying table is based on that published by the writer in *Classification of Marine Trias*, but revised and brought up to date so as to include the stratigraphic work of the past two years, and to give a satisfactory basis for the correlation of marine Triassic sediments for all known regions. Of course it is only tentative, merely the opinions of several men engaged in this study; but the wide distribution of such zone faunas as

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[1] Bull. Geol. Soc. Amer., Vol. III, "Jura and Trias at Taylorville, California," pp. 397–400.

[2] JOUR. GEOL., Vol. II, No. 6, 1894, "The Metamorphic Series of Shasta county, California, and JOUR. GEOL., Vol. III, No. 4, "Mesozoic Changes in the Faunal Geography of California."

[3] JOUR. GEOL., Vol. IV, No. 4, "Classification of Marine Trias."

[4] Denksch. K. Akad. Wiss. Wien. (Math. Nat. Kl.), Bd. LXIII, 1896, "Beiträge z. Kennt. d. Obertriadischen Cephalopoden Faunen des Himalayas.

CORRELATION OF MARINE TRIASSIC SEDIMENTS.

Series	Stage	Substage		Zone Fossil	Mediterranean Region	Oriental Region	Arctic-Pacific Region	American Region
BAJUVARIC	Rhaetic		22	*Avicula contorta*	Koessen Beds		*Stenarcestes* beds of New Caledonia	
	Noric	Sevatic	21	*Sirenites argonautæ*	Noric Limestone of Hallstadt Balia-Maden in Asia Minor		*Monotis* beds of Rotti	*Pseudomonotis* beds ? of Peru of Queen te Islands
			20	*Pinacoceras meitternichi*		*Halorella* beds of the Pamir		
		Alaunic	19	*Cyrtopleurites bicrenatus*				Swearinger slates, Californian Hosselkus limest'ne
		Laciacic	18	*Cladiscites ruber*		Himalayan Noric limestone		
			17	*Sagenites giebeli*				
TIROLIC	Karnic	Tuvalic	16	*Tropites subbullatus*	Sandling beds	Himalayan Karnic limestone	*Daonella* beds of Rotti *Juvavites* beds of Tonquin, China	with *Subbuilatus* and *Trachyceras* faunas Trias Charlot
		Julic	15	*Trachyceras aonoides*	Raibl beds			
		Cordevolic	14	*Trachyceras aon*	St. Cassian beds			Halobi*a* beds
	Ladinic	Longobardic	13	*Protrachyceras archelaus*	Wengen beds		Nipon beds of Japan	Pitt Shales of Shasta County, Star Peak beds of
		Fassanic	12	*Dinarites avisianus*	Marmolata beds			
			11	*Protrachyceras curionii*	Buchenstein beds			
DINARIC	Anisic	Bosnic	10	*Ceratites trinodosus*	Upper Muschelkalk	*Ptychites rugifer* beds of the Himalayas	*Daonella* beds Spitzenbergen Beds of Russkij and Olenek	California Nevada
		Balatonic	9	*Ceratites binodosus*	Lower Muschelkalk	*Sibirites prahlada* beds of the Himalayas		
	Hydaspic		8	*Stephanites superbus*		Upper *Ceratite* limestone of the Salt Range	*Posidonomya* beds	
SCYTHIC	Jakutic		7	*Flemingites flemingianus*	Zone of *Tirolites cassianus* Werfen beds of the Tyrolean Alps *Tyrolites* beds of Djulfa in Armenia	*Ceratite* limestone of the Salt Range *Subrobustus* beds of the Himalayas	Olenek beds of Siberia	*Meekoceras* beds of ? Idaho Santa Ana limestone of California
			6	*Flemingites radiatus*				
			5	*Ceratites normalis*				
	Brahmanic		4	*Proptychites trilobatus*		*Ceratite* marls of the Salt Range	Beds of Ussuri and Russkij	*Ceratite* limestone of Inyo County, California
		Gandaric	3	*Proptychites lawrencianus*				
			2	*Gyronites frequens*		Lower *Ceratite* limestone of the Salt Range		
		Gangetic	1	*Otoceras woodwardi*		*Otoceras* beds of the Himalayas		

those of the *Meekoceras* beds of the Lower Trias, of the *Trachyceras* and *Tropites subbullatus* faunas of the Tirolic series, and of the *Pseudomonotis* beds in the Arctic-Pacific region, makes interregional correlation a much easier task.

The nomenclature of the table is that of Diener, Waagen and E. von Mojsisovics,[1] with the exception that *Ladinic* has been substituted for *Noric*, and *Noric* instead of *Juvavic*, the controversy between Bittner and v. Mojsisovics having been settled by a committee of the leading Austrian geologists[2] agreeing to make this change, and by this recommendation being in part accepted by v. Mojsisovics. It is immaterial to American stratigraphers which names are used, but since the Alpine Trias is the type of the marine formation of this age we must use the original formational names given by the Austrian geologists, and in the original sense. It is, therefore, a cause for congratulation that the committee report has been so widely accepted, and for regret that E. von Mojsisovics is still inclined to cling to his new term *Juvavic* for the Hallstadt beds which he formerly called *Noric*.

LOWER TRIAS.

The Santa Ana limestone.—The first Lower Trias recognized in California was found by Dr. H. W. Fairbanks in a hard black siliceous limestone on the west slope of the Santa Ana range, Orange county, California. The fossils were submitted to the writer, and proved to be: a trachyostrachan ammonite, not otherwise determinable, an undetermined brachiopod, and *Pseudomonotis* aff. *clarai*. The ammonite makes the Mesozoic age probable, and the pelecypod makes almost certain the Lower Triassic age, for *Pseudomonotis clarai* is diagnostic for the Werfen beds, upper part of the Alpine Lower Trias. It seems quite possible that this formation in California may be the connecting link between the Mediterranean and the Oriental regions, for the furthest known eastward extension of the Mediterranean Lower Trias, that of Djulfa in Armenia, is still of Alpine type, with *Tirolites*? and *Pseudomonotis* conf. *clarai*. The connection that existed in Permian time between India and eastern and southern Europe, through Asia Minor, seems to have been cut off in the Lower Trias. But these faunas are too meager for this to be much more than mere speculation.

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[1] Sitzungsberichte k. Akad. Wiss. Wien. Bd. CIV. Abth. I. Dec. 1895. Entwurf einer Gliederung der Pelagischen Sedimente des Trias-Systems.

[2] Zur Ordnung der Trias-Nomenclatur. Wien 1898.

	Permian	Lower Trias			Middle Trias	Upper Trias
		Brahmanic		Jakutic		
		Gangetic	Gandaric			
Lytoceratidæ, *Nannites*		Himalayas ×				Mediterranean and California ×
Pinacoceratidæ, *Clypites*?			Salt Range ×			
Meekoceratidæ, *Koninckites*		Himalayas ×	Salt Range ×	Salt Range, rare ×		
Meekoceratidæ, *Meekoceras*		Himalayas ×	Salt Range ×	Mediterranean, Idaho ×	Salt Range ×	
Meekoceratidæ, *Kingites*		Himalayas ×	Salt Range ×	Olenek and Salt Range ×		
Meekoceratidæ, *Gyronites*?			Salt Range ×	Salt Range, Olenek ×		
Ptychitidæ, *Xenaspis*	Salt Range ×	Himalayas ×	Ussuri ×		Himalayas × ?	
Celtitidæ, *Dinarites*				Mediterranean Salt Range Arctic ×	×	
Tropitidæ, new genus						

The Ceratite limestone of Inyo county.—In 1896 Dr. C. D. Walcott discovered some ammonite-bearing limestones in Inyo county on the east side of Owens' valley ten miles east-northeast of Lone Pine, two or three miles south of the Eclipse mill, and about 3000 feet up above the mill, on the trail from Independence ever the Inyo range to Saline valley. The fossils submitted to the writer were badly crushed and distorted, owing to the partial metamorphism that the limestone has undergone, so that they were not in condition for description of genera and species, nor for identification with known species. But the septa permitted the identification of several genera of ammonites with considerable certainty; none of them were higher than the ceratite stage, and some retained simple goniatitic septa, a combination which, in itself, would point to Lower Triassic age, even if all the genera were new. The genera determined were all ammonites, no others being recognizable. The list is given on page 780, showing the range and occurrence of these genera.

In the above list it will be seen that most of the genera are confined to the Lower Trias, or Scythic series, of India, and that while most of them range through the Brahmanic and Jakutic stages, they nearly all reach their greatest development in the Brahmanic, and are rare outside of it. Thus it is probable that the Ceratite limestone[1] of Inyo county belongs to the Brahmanic. Another bit of evidence is the occurrence of some undetermined ammonites not included in the above list, resembling *Otoceras*, which in Armenia occurs in the highest Permian and in the Himalayas in the lowest Trias, only a few feet above the highest *Productus* beds, the top of the Palæozoic.

This fauna is wholly unlike anything in Europe, or indeed anywhere else outside of India, but it resembles that described from the Salt Range by Waagen,[2] and from the Himalayas of India, and Ussuri Bay by Diener.[3] Some years ago it was pointed out by Mojsisovics in *Arktische Triasfaunen* that the Lower Trias of Idaho was closely related to that of the Arctic-Pacific region, although no certain comparison could be made. In the Californian fauna we have the best means of comparison with the Indian ammonites, through the monographs of Waagen and Diener. We may, then, assume as certain a connection of the Californian waters with the Oriental region during Brahmanic or Jakutic time, forming the *Arktis* of Mojsisovics, and a separation from the Mediterranean Triassic sea or *Thetys* of Suess. How intimate this connection was we cannot know until material good enough for the identification of species is found.[1]

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[1] So-called, because of the prevailing ceratitic type of the ammonites.

[2] Pal. Indica. Salt Range Fossils. Fossils from the Ceratite Formation.

[3] Pal. Indica. Ser. XV. Himalayan Fossils. And *Mém. Com. Géol. St. Petersbourg*. Vol. XIV. No. 3. Triadische Cephalopodenfaunen der Ostsibirischen Küstenprovinz.

The danger of inferring separation of provinces on the basis of too few fossils is shown by the following diagram, illustrating the relations of the Lower Trias of the Salt Range with that of the Himalayas, according to Diener.[2]

Himalayas	Salt Range
Muschelkalk	Upper Ceratite limestone
Subrobustus beds	Ceratite sandstone
Almost unfossiliferous	Ceratite marls
	Lower Ceratite limestone
Otoceras beds	Unfossiliferous
Permian	

The Permian faunas are closely related in both, and that of the Subrobustus beds is, in part, identical with the fauna of the Ceratite sandstone, while between these two horizons each province has unfossiliferous beds corresponding to strata rich in ammonites in the other. It is not, therefore, a justifiable inference that they were connected in Permian time, and separated after that until Jakutic time.

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[1] The writer hopes during the season of 1899 either to visit this locality in person, or to send some of his students there.

[2] Mém. Géol. Surv. India. Ser. XV. Himalayan Fossils. Vol. II. Part I, p. 177.

Tirolites and other members of the Tirolitinæ are conspicuously lacking in the Indian region, and this is true also of the Inyo beds. On the other hand *Dinarites* is entirely lacking in the Lower Trias of the Himalayas, and in the Salt Range below the Ceratite sandstone of the Jakutic, the species described as *D. minutus* Waagen, from the Ceratite marls, having turned out to be a *Ceratites.* And since the Dinaritinæ are known in the Lower Trias of the Mediterranean region, the Inyo fauna seems to have been intermediate between that and the Indian, although much more intimately connected, during the Brahmanic stage, with the Oriental region.

Gabb[1] cites *Goniatites lævidorsatus* Hauer from a locality thirteen miles north of Owens' Lake, from the foothills on the east side of the valley. E. von Mojsisovics[2] says that this ammonite is not Hauer's species, and not even in the same genus with it, *Celtites*, but belong to the group of *Ceratites obsoleti*, subgenus *Danubites*, chiefly characteristic of the Lower Trias. It seems, therefore, that the credit for the discovery of this formation in California must be given to the State Geological Survey under Whitney.

MIDDLE TRIAS

Of the faunal relations of Middle Trias little is to be said, because undoubted fossils of this age are not yet known in the state, nor, indeed, anywhere in America. The writer[3] has described a series of siliceous slates that probably belong in part to the Muschelkalk, but the evidence is merely stratigraphic, the known fossils being too poor to be of any use. The occurrence, at Silverthorn's Ferry on Pitt River, of a number of indeterminable ammonites, one of which resembles *Ptychites*, holds out the hope of future decisive discoveries. It seems likely, too, that a part of the Star Peak beds of Nevada may eventually be shown to belong here, as Professor Hyatt has long claimed, but as yet the evidence is not convincing.

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[1] Pal. Calif., Vol. I, p. 21.

[2] Arktische Triasfaunen, p. 20.

[3] JOUR. GEOL.; Vol. II., 1894, No. 6. The Metamorphic Series of Shasta county, California.

UPPER TRIAS.

The Upper Trias of the Genessee valley, Plumas county, was discovered and described by the Whitney Survey; its fauna is decidedly Alpine in character, although all the species thought by Gabb to be identical with European forms have since been shown not to agree with them. Since that time Professor Hyatt[1] has visited this locality, and has added greatly to the fossil list, some of the newly discovered ammonites being doubtfully referred to Alpine species.

The Upper Trias of Squaw creek, Shasta county, was discovered by Dr. H. W. Fairbanks, who called the writer's attention to the locality. The writer has since spent a good part of three field seasons in collecting fossils, and in studying the stratigraphy of that region; part of the results of this work has already appeared in the JOURNAL OF GEOLOGY.[2] In the papers referred to the most important species have been listed, although later field and museum study has changed the list considerably, adding many new ones, and dropping several. The fauna contains a large number of *Trachyceras* (subgenus *Protrachyceras*), *Clionites*, *Arpadites*, *Polycyclus*, *Sirenites*, *Tropites*, *Eutomoceras*, *Juvavites*, *Sagenites*, *Nannites*, *Miltites*, *Arcestes*, *Halobia*, etc., of decidedly European type. Dr. E. von Mojsisovics is of the opinion that several of these may be identical with species characteristic of the Tyrolean Alps. The greater part of the fauna belongs to the Karnic stage, zone of *Tropites subbullatus* Hauer, which characteristic ammonite of the Sandling beds is also present in great abundance in the Squaw creek limestone, showing all the varieties known in the Alps.

In the papers cited above the writer has called attention to the occurrence of species *Trachyceras* along with *Tropites subbul-*

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[1] Bull. Geol. Soc. Amer., Vol. III, pp. 397–400.

[2] Vol. II, 1894, No. 6; Vol. III, 1895, No. 4; Vol. IV, No. 4, 1896.

latus Hauer, *T. torquillus* Mojs., *T. Telleri* Mojs., and many others characteristic of the Tuvalic substage. In the Hallstadt beds of the Tyrol no such association as this is known; the *Trachycerata* do not occur higher up than the Julic substage, zone of *Trachyceras aonoides*, nor does the Subbullatus fauna appear below the Tuvalic. It is, therefore, a question as to whether the Julic fauna survived longer here than elsewhere, or whether the *Tropites subbullatus* fauna reached here earlier, in middle Karnic time. There is not yet enough evidence to decide this, but it all points to the latter alternative. The *Tropites* fauna is an immigrant fauna wherever known, appearing suddenly without local ancestors in the Alps, the Himalayas, and in California, in the upper part of the Karnic stage; thus it may be that its occurrence in California marks an earlier appearance, for it was probably endemic in the American region. In addition to this, the *Trachycerata* associated with the Subbullatus fauna all belong to the subgenus *Protrachyceras*, which is supposed to be characteristic of a lower horizon than *Trachyceras* itself, which genus has recently been found in the Upper Karnic of the Himalayas. Further, the Subbullatus fauna did not all reach California at the same time, *Homerites semiglobosus* Hauer, not appearing here until all the *Trachyceras* fauna, and most of the *Tropites*, with which it is associated in the Alps, had become extinct.

We have in this occurrence an interesting study in homotaxis; the *Trachyceras* fauna is homotaxial all over the world, so is the Subbullatus fauna, and yet their occurrence together proves that neither fauna was synchronous in its appearance in various parts of the earth, and that even the order of appearance of the two faunas is not the same in all regions.

The most comprehensive review that has appeared on the faunal geography of the Upper Trias is the chapter by Dr. E. von Mojsisovics, "Die Meere der Trias-Periode,"[1] in which all that is known of the distribution and relations of faunas of this period is given, and several pages devoted to the western American Trias, based on the published writings of Gabb, Meek, Hyatt, Whiteaves and the writer, and upon personal communications from Hyatt and the writer. Mojsisovics here takes the view that the occurrence together of the Subbullatus fauna and *Trachyceras* in India and California shows a survival of the latter group beyond its time elsewhere; this is more likely true of India, where the survival consists of single species of genuine *Trachyceras*, but in California the fauna is almost too large to be a survival.

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[1] Denkschriften d. K. Akad. Wiss. Wien, Bd. LXIII, 1896, "Beitr. z. Kenntniss d. Obertriadischen Cephalopoden Faunen des Himalayas."

The most interesting fact brought out by a comparison of the Upper Trias of California with that of India and the Alpine Mediterranean region is its near relationship with the latter, most genera and many species being common to the two regions. On the other hand, not many genera and no species are now known to be common to California and India; this is contrary to what we should expect, knowing that during the Lower Trias California was closely connected with India, as shown by community of genera and possibly of species, and also that during this same time neither India nor California was closely connected with the Mediterranean Triassic sea. Great changes in physical geography must have taken place about the end of Lower Triassic time, of which we have a partial record; during the Muschelkalk several species are common to the Indian, the Arctic-Pacific, and the Mediterranean regions, thus showing an opening of connection between regions that before were separated.

This relationship of the Californian to the European faunas persists until after the middle of the Jurassic formation, when the Boreal fauna comes in; towards the end of the Lower Cretaceous the connection with India is again established.

It is hard to see how anyone that has studied the changes of faunal geography undergone by the western American region since Paleozoic time could believe in the permanency of the oceanic basins as they now exist. These shifting faunal relations can only mean rising and sinking of continental margins, cutting off and facilitating intermigration, alternately aiding and obscuring interregional correlation. JAMES PERRIN SMITH.